Environmental Assessment of an Offshore Oilfield

Funded by the EPA through the National Oceanic and Atmospheric Agency, this environmental study is the first major effort assessing the potential pollution from routine development and extraction of offshore energy reserves

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EDITOR'S NOTE: The following is a condensed version of a paper presented by the authors last year at the 10th Annual Offshore Technology Conference in Houston.

In 1975, the Galveston Laboratory of the National Marine Fisheries Service was given responsibility to document environmental conditions of an active oil and gas field in the northwestern Gulf of Mexico. The site chosen for the study was Shell Oil Company's Buccaneer oil and gas field, about 32 nautical miles southeast of Galveston, Texas, in about 65 feet of water. The field was selected because it has been in production since 1960, allowing ample time for the development of oilfield-associated marine communities; it is isolated, eliminating or reducing substantially the influence of other fields; it produces oil and gas, and releases production brines constituting one of the major sources of contaminants; and its location simplifies logistics and reduces the cost of research.

Objectives of the study are to identify and document the extent and types of biological, chemical, and physical alterations of a marine ecosystem associated with development of and production from an oilfield; to determine the specific pollutants, their quantity, and their effects on various components of the marine ecosystem; and to develop capabilities to describe and predict fate and effects of oilfield contaminants in major components of the marine ecosystem.

Exploratory drilling began in the Buccaneer field in 1960 with mobile drilling rigs. As a result of the exploratory drilling, permanent platforms were constructed. All subsequent drilling and production activities have been conducted from these platforms. A total of 17 structures has been installed: two production platforms, two living quarters platforms, and 13 satellite structures (well jackets).

The field reserves are primarily gas, but both gas and oil are produced. In total, 81 wells have been drilled. Of these, 56 were completed and 25 were plugged. Of the 34 wells now active, 31 are gas completions and three are oil completions.

There is no history of major oil spills reported from this field. There have been reported losses of a barrel of oil upward because of mechanical failure of various equipment. From September 1973 through September 1975, a maximum of 6.1 barrels was reportedly spilled, and three of those barrels were from an unknown source.

The Buccaneer field area apparently was a good shrimping ground before the field was established, and apparently has remained so. During commercial shrimping operations, small fishes and other organisms captured with shrimp in the trawls are culled from the catch and returned to the water. These organisms may provide a supplemental food source that would be less easily available to pelagic predatory fish in the absence of commercial fishing.

A pilot study in 1975 showed the Buccaneer field was a suitable site for achieving objectives of the environmental assessment. The first full year of research (1976-1977) was directed toward ecological characterization of the study area. Sampling surveys in the field and adjacent unaltered (control) areas included hydrographic variables, sediments, trace metals, hydrocarbons, organic carbon, and planktonic, benthic, and pelagic faunal communities. A separate survey measured the effects of the Buccaneer field structures on faunal community composition and aggregation. Results of the first year of work were released in December 1977.

Metal concentrations for bottom sediment samples showed enriched concentrations of lead, zinc, and strontium near production Platforms 288-A and 288-B and near one of the satellite platforms. Analysis of organisms, including fish, shrimp, squid, ichthyoplankton, and barnacles also were conducted. For the most part, trace metal concentrations in these animals were not abnormally high, with the exception of high cadmium (up to 25 ppm) and strontium (up to 100 ppm) levels in several barnacle specimens. The source of these contaminants was not determined.

Buccaneer crude oil contained 18 percent n-alkanes, together with branched alkanes and aromatic hydrocarbons. The condensate contained a comparable amount of hydrocarbons, but with relatively greater concentrations of more volatile components. Alkane concentration of the produced brine discharge ranged up to nine ppm. There was evidence of petroleum-derived n-alkanes (up to 35 ppb) in surface-seawater samples, but alkanes observed in bottom-water samples might have been bacterial in origin. Flesh from barnacles taken 7.5 to 15 m below the surface was free of petroleum, but there was evidence of petroleum alkanes in some flesh samples from barnacles collected near the surface. Most whole barnacle samples (shell and flesh intact) apparently contained petroleum-derived al-

kanes. Of four species of shrimp examined, only one specimen was found to contain petroleum alkanes.

There was evidence of erosion of sediments in the field, with erosion predominating over deposition, indicating that any carbonaceous pollutants likely would not accumulate inside the field. The isotopic distribution pattern suggested deposition of hydrocarbons or associated carbon pollutants, but this was inconsistent with radio-carbon dating, which indicated that erosion, rather than deposition, had occurred within the field.

The Buccaneer field and adjacent waters were shown to be highly productive in ichthyoplankton eggs and larvae. Anchovies comprised 38 percent of all larvae collected. Other major groups collected were the gobies, flatfishes, jacks and scads, and drums. The highest abundance of larvae occurred during August, and the highest abundance of eggs occurred during May. The lowest abundance of larvae occurred in February. The study area appears to be a major spawning ground for callionymids, clupeids, engraulids, scombrids, sciaenids, and soleids. Larvae of little tuna, scaled sardine, thread herring, sardine, and silver perch was caught only in the oilfield. The Buccaneer field structures apparently serve as artificial reefs, attracting fish that use the area for spawning, feeding, and shelter.

Samples of demersal finfishes and macro-crustaceans were taken with trawls, traps, and by hook and line. The most productive sampling method was trawling, which showed that the dominant species of demersal finfish were bay whiff, longspine porgy, dwarf sandperch, Atlantic croaker, and pancake batfish. The dominant crustaceans were sugar shrimp, rock shrimp, chevron shrimp, and brown shrimp.

The demersal species were taken during four seasons and in all three areas (around platforms and in two unaltered areas sampled by trawling). Brown shrimp and sugar shrimp were taken in greater numbers near the platforms than in unaltered areas. Buccaneer field structures limit commercial trawling operations to open water areas between the structures, whereas sample trawling using smaller trawls could be conducted closer to these structures. This may have contributed to the higher catches near the structures, which may protect certain species from capture during commercial operations.

Using sampling methods including trolling, longlining, and gillnetting, the major species caught were red snapper, king mackerel, dolphin, Atlantic spadefish, bluefish, little tunny, and cobia. Gillnetting was not effective. Longlining caught mostly sharks. Catch (number of fish) per hour of troll sampling was highest near production platforms and well jackets, lowest in waters among the oil- and gas-field structures, and intermediate in areas outside the field, suggesting that pelagic fish aggregated around the structures. The highest amount of recreational fishing effort in the Buccaneer field occurred in late August and September. Of the total number of boats observed participating in recreational fishing in the area, 77 percent were engaged in bottom-fishing, 17 percent in trolling, and six percent in diving activities. All of the diving effort and 98 percent of the bottom-fishing and trolling effort occurred immediately around producing Platforms 288-A and 288-B.

The existing fouling community on the platforms was found to be dominated by the large barnacle (Balanus tintinnabulum), which provided a matrix of crevices in which other invertebrates were found. Sample surfaces of the structures that were scraped clean were recolonized primarily by hydroids, green algae, and sponges. Atlantic spadefish, sheepshead, crested blenny, and high hat were the predominant resident fishes associated with the structures. Stomach-content analysis indicated that these resident fishes and cocoa damselfish fed extensively on the fouling community. The benthic fauna directly below the structures apparently was enriched by the food organisms represented by barnacles and other invertebrates dislodged from the structures. Growth rates of several mollusks were sufficiently rapid to permit adult size to be attained in less than one year.

The black tern accounted for 51 percent of the total number of individual birds observed. Migratory land birds accounted for 12 percent of the total number of individuals but represented 86 percent of the 87 species identified. The remainder of the species and individuals were seasonal residents of the general area. Of the 71 birds observed dead on production Platform 288-A, all were members of the migratory land-bird group. On the basis of this survey, it was concluded that the effect of Buccaneer field structures on migratory marine birds was negligible, and the effect on resident marine birds seemed beneficial in providing food and resting areas. The effect on migratory land birds seemed detrimental, but the question remains whether these birds would have lived if they had not landed on the platform.

In the second year (ending May 1978) of study of the Buccaneer field, emphasis was placed on investigation of the field area, stressing comparisons between structures (producing platforms) from which oilfield effluents were discharged with those (well jackets) from which no effluents were discharged.

Investigations were continued on hydrography; sediments and trace metals; hydrocarbons; ichthyoplankton, pelagic, reef and demersal finfishes, and macro-crustaceans; and effects of structures. The studies of organic carbon and benthos, completed during the first year, were terminated. Additional investigations including bacteria, shrimp bio-assays, and ecological modeling were initiated. Results of this work are

tentative at this time and represent the first half (ending in December 1977) of the second year of study.

Six trace metals present in anomalously high concentrations in sediment samples from Buccaneer field were identified as barium, cadmium, nickel, lead, zinc, and strontium. These can be classified into three groups with regard to possible source of contamination: 1) contamination related to metallurgy of drilling structures (cadmium, nickel, lead, and zinc); 2) contamination related to the drilling operations (barium); and 3) contamination related to produced water (strontium).

Up to 12 ppm alkane was found in a whole barnacle (shell plus intact animal) collected at the surface near the produced water discharge of Platform 288-A. Weathered oil was found in two of 12 brown shrimp, in one of three pink shrimp, in two of three mantis shrimp, and in two of three sugar shrimp analyzed.

In the survey of ichthyoplankton, the anchovies were the most abundant larvae in the Buccaneer field, together with drums, flatfishes, gobies, and clupeids. Pelagic and reef fish under production Platform 288-B and a nearby well jacket were more concentrated at 4.6 and 12.2-m depths than near the surface. Dominant species observed were blennies, Atlantic spadefish, gray triggerfish, blue runner, and sheepshead.

The fouling community of the structures in the Buccaneer field were categorized into two components, the "habitat formers" (barnacles, bivalve mollusks, etc.) and the "fouling mat" (a sometimes multilayered interspersion of algae, bryozoans, hydroids, sponges, etc.). Each of these two components had an association of cryptic species. The dominant habitat-former was the barnacle. The dominant cryptic species associated with the fouling mat included polychaetes, nematodes and amphipods. Total biomass levels of the fouling

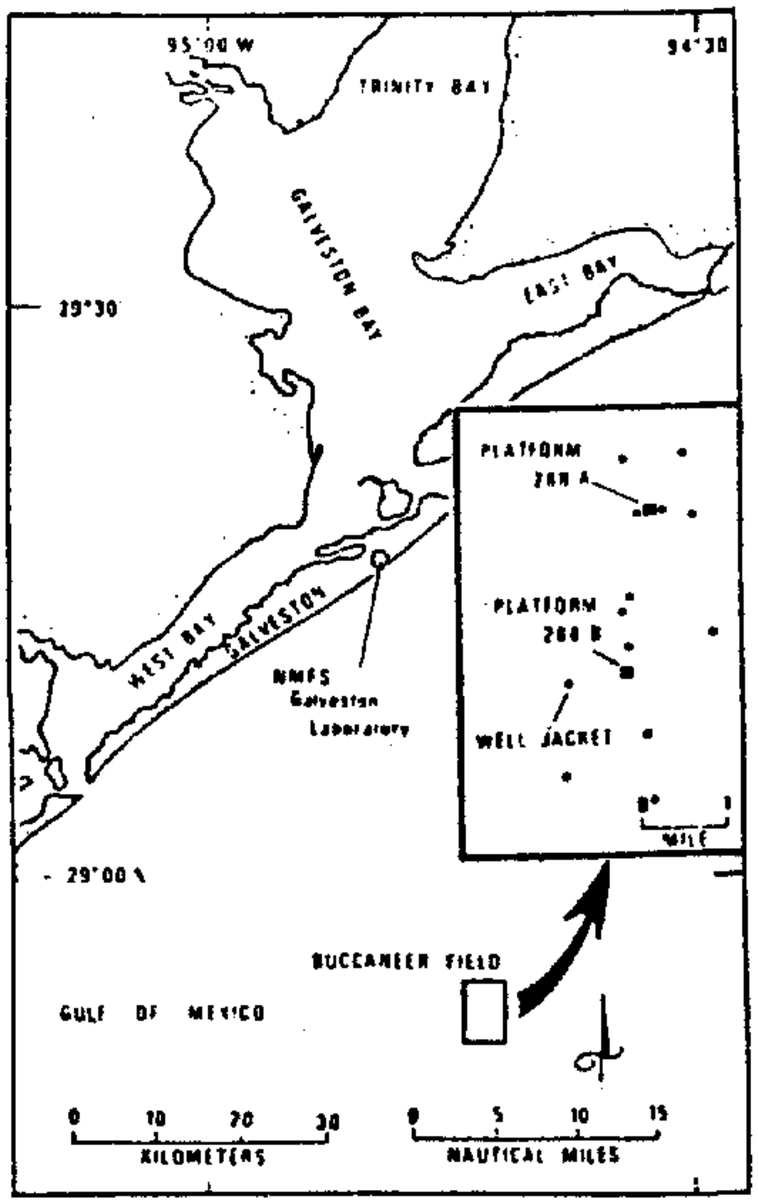

FIG. 1 - LOCATION OF BUCCANEER FIELD.

community seemed much reduced in the area of the produced water discharge. Population size of Atlantic spadefish was directly proportional to size of structures in the Buccaneer field; i.e., population density was similar at production platforms and a well jacket. In contrast to findings of the first year, it was found that the Atlantic spadefish feeds primarily on meroplankton.

Total colony-forming units enumerated by plate counts showed 200 to 300 bacteria per milliliter of seawater, and between 60,000 and two million bacteria per gram dry weight of sediment. The distribution in most sampling sites showed a typical shallow-water pattern with the larger microbial numbers found in the sediment and in the water mass near the sediment. There was a greater percentage of oil degraders within the platform area as compared with the control site. Petroleum-degrading bacteria were more common in the upper water, decreasing in number near the bottom. The percentage of oil-degrading bacteria was lowest in the sediment. Dilute produced water did not adversely affect or inhibit the bacteria collected from the platform area. There seemed to be no difference in growth of oilfield isolates in produced water (presumably containing bactericides) collected from the platform discharge and produced water known to be free of added bactericides.

In determining acute toxicity and chronic effects of Buccaneer field produced water on brown shrimp and white shrimp, at test temperature of 25° C ± 1° and concentrations of 10,000 ppm (v/v, produced water discharge/diluent seawater) or greater, all animals died in less than 29 hours. In three hours, 100 percent mortality occurred at 500,000 ppm. At 1,000 ppm, only ten percent died after 96 hours of exposure.

Activities during the third year will focus on sources, fate, and effects of offshore oil- and gas-field contaminants, including 1) surficial sediments and suspended particulate matter; 2) shrimp and fish bioassays, 3) pelagic, reef, and demersal finfishes and crustaceans, 4) bacteria, 5) structure-associated communities, 6) circulation patterns, 7) hydrocarbons, biocides and sulfur, 8) heavy metals, 9) fate and effects modeling, and 10) hydrodynamic modeling. Emphasis will be placed on dominant modes of transport of contaminants and dynamics of dominant food webs as they relate to sources, fate, and effects of contaminants.

The multidisciplinary environmental assessment of the Buccaneer field will contribute substantially to the understanding of effects of an offshore oil and gas field on the marine ecosystem. Such understanding is essential to development and extraction of offshore energy reserves in ways that protect, maintain, and preserve offshore marine ecosystems and their important commercial and recreational fisheries resources and in ways that are not harmful to man.